the greater the attractive force, enables us to enunciate the following law, the truth of which I am at present unable to verify for want of sufficient experimental data: those solids, other things being equal, which evolve the greater amounts of heat of chemical decomposition in changing from simple mixtures to compound solids, are those which have less specific heat per atom. The phrase, 'other things being equal,' in the above statement, refers to the fact that similar compounds which are chemically similar are in strictness comparable. Many other circumstances, moreover, besides want of chemical similarity, may, in special cases, mask the experimental results; yet the truth of the law should be clearly recognizable in any general comparison of specific heats with the heat of formation of compound solids.

Similar principles evidently apply to the cases in which simple solids are permanently decreased in volume by hammering or compression; for then greater cohesive forces are brought into action, and the specific heat is diminished. It remains to be shown, in conclusion, that thermal equilibrium, which has been established by collisions of gaseous and solid molecules, will continue to exist when its continuance depends upon radiations between equal and similar ultimate atoms which are set in vibration by molecular collisions; or, to state it differently, it remains to be shown that the ultimate atoms of a gas and a solid in contact, each have the same mean vibratory energy with respect to each of their degrees of freedom with respect to each other. This appears to be a direct consequence of the laws of constrained motion which have been considered in this and previous papers. It is only necessary that the impacts of a pair of solid molecules with each other should be such as to mutually impart and receive the same mean amounts of energy as would those of a gaseous and a solid molecule at the same temperature, to cause it to be a matter of indifference whether a given solid molecule is struck by another solid molecule or by a gaseous molecule; and, when so struck, each ultimate atom will receive its proper proportion of energy, whether it form part of a solid or of a gaseous molecule.

It is my intention to return to this subject hereafter, and to treat the vibrations of ultimate atoms more at length, in the hope of being able to show, more precisely than has been done so far, how the characteristic differences in the spectra of solids and gases arise.

H. T. EDDY, Ph.D.

CLIMATE IN THE CURE OF CONSUMPTION.—I.

THE prevalence of phthisis pulmonalis is such a well-attested fact, that to adduce statistics to prove it would seem to be labor thrown away. Since the eradication of small-pox in consequence of the introduction of vaccination, phthisis heads the list as the prime cause of the large mortality. The insurance companies recognize the fact, and the statistics of the New-York mutual life-insurance company show, that between the ages of twenty and thirty years the mortality from phthisis is thirty-three per cent of the whole mortality. The U. S. census for 1870 shows that in the state of Maine the mortality from consumption was fifty per cent for the same ages.

Equally well known is the belief in climate as a cure for the disease. There are certain well-recognized climatic conditions known to be favorable to the prophylaxis and cure of the disease. This knowledge is largely empirical, based upon trial and observation; but there is, underlying it, a substratum of conviction, that is justified, on the one hand, by careful clinical observations, and, on the other, by facts ascertained by carefully conducted experiments.

The writer proposes, in the thoughts to be presented, to make these various elements his tests in searching out a desirable climate in the United States for the cure of phthisis. He offers, as his data for forming an opinion, carefully compiled tables, furnished by the Signal-service bureau, U.S.A.; and he wishes to emphasize the fact, at the outset of his remarks, that a climate may become desirable quite as much by comparison as on account of its intrinsic properties; that even though it may not possess in itself all desirable qualities, yet it may contain so many as to be, by comparison with others, the climate par excellence. With this thought in view, the writer has prepared tables embracing all the chief resorts in this country for phthisical invalids, — tables embracing a range of the whole country, from Jacksonville to St. Paul, and from Boston to Los Angeles.

He has given the data for Augusta, Ga., as the best substitute for Aiken, S.C., at which place there is no signal-station; and in doing so he thinks that he is presenting data which will fairly represent the climatic conditions of Aiken.

He wishes to gratefully acknowledge his indebtedness to the chief signal-officer, U.S.A., to the observers at each of the stations included in the tables, and especially to Sergeant F. M. Neal of the Denver station, for their kindness in furnishing him with the data from which the tables are compiled.

TABLE I.

STATION. The figures giving the elevation represent the height of the barometer above sea-level.	I. Elevation.	II. Mean 10 yrs. Barometer.	III. Mean 4 yrs. Relative humidity.	IV. Mean 4 yrs. Absolute humidity.	V. Mean 10 yrs. Precipitation.	VI. Mean 10 yrs. Temperature.	VII. Mean 5 yrs. Prevailing wind.
Augusta, Ga.	183	30.140	69.2	4.56	48.98	64°.2	N.E.
Jacksonville, Fla.	43	30.030	69.0	5.38	55.94	69°.2	N.E.
Boston, Mass.	142	29.840	68.5	2.66	49.47	48°.5	W.
Newport, R.I.	34	29.950	74.3	3.07	50.20	50°.3	S.W.
New York, N.Y.	164	29.857	70.2	3.02	42.70	51°.3	N.W.
Philadelphia, Penn.	52	30.084	68.8	3.17	41.89	53°.2	S.W.
Chicago, Ill.	661	29.317	69.2	2.77	35.47	49°.3	S.W.
St. Paul, Minn.	811	29.133	67.3	2.23	29.59	43°.9	S.E.
Denver, Col.	5,294	24.778	45.8	1.81	14.77	49°.1	S.
Santa Fé, N. Mex.	7,046	23.263	41.4	1.61	14.17	48°.5	E.
Salt Lake, Utah	4,348	25.644	40.3	1.76	17.52	51°.8	N.W.
Los Angeles, Cal.	350	29.647	65.8	3.77	18.97	59°.8	W.

Elevation.

The effect of a rise in elevation is to diminish the atmospheric pressure. The method of measuring this effect is by means of the mercurial barometer. Disregarding the variations attributable to changes in temperature, humidity, and latitude, it can be broadly stated that the barometer will fall one inch for a rise of 857 feet above sea-level, two inches for a rise of 1,743 feet, three inches for a rise of 2,661 feet, etc.; or, for the purposes of a rough calculation, it may be said that the barometric depression is one inch for every thousand feet of elevation. This depression would indicate a diminution in atmospheric pressure of one-sixth in weight for an elevation of 5,000 feet; or, to state this fact in another way, the atmospheric pressure at sea-level being 15 lbs. to the square inch, at 5,000 feet it would be one-sixth less, or 12½ lbs. To illustrate: if the pressure on the entire surface of the body of a man of middle size be 35,560 lbs. at sea-level, at 5,000 feet it would be 29,635 lbs., a diminution of nearly three tons.

The question for us to consider is, what effect this diminution of pressure has upon the vital functions with reference to the cure of phthisis.

1. *Effect on circulation.* — The heart is a muscular organ, habituated to expend a certain amount of force, which may be roughly estimated as 75,000 kilogrammetres, or 542,475 foot-pounds, *per diem*. To accomplish this work at sea-level, the heart makes 72 beats a minute, or 103,680 beats a day. Allowing, now, an increase of two beats a minute for every thousand feet of elevation, at 5,000 feet there will be an increase of 10 beats a minute, or 14,400 beats a day, — an increase in work equal to about 74,744 foot-pounds in a day.

This in itself would prove that such an elevation is to be avoided in those cases where an enfeebled heart is struggling to overcome the disadvantages produced by organic lesions.

What effect does this increase of heart-work have upon the circulation? The rapidity of circulation is influenced by the force and rapidity of the heart's beat, and by the diminution of the peripheral resistance. At an elevation of 5,000 feet, each of these causes would be at work. To just what extent they work, in producing given results, it is impossible to say; but, allowing that the peripheral resistance and the force of the heart's beats remain the same at 5,000 feet as at sea-level, an increase in frequency of ten beats per minute would indicate, that, on account of this one factor, the blood would make 29,622 additional circulations through the system *per diem*. What effect would this have upon the disease in question?

It is a frequent remark that both waste and repair are more rapid at high altitudes than at sea-level. Experience amongst physicians shows that cases of fibrinous pneumonia are more acute and more rapid in their results at

high altitudes than at sea-level. My own experience is, that resolution in such cases is more rapid, and that the chest 'clears up' sooner. May not this be explained on the ground of the increased rapidity of circulation? We know that the clearing-up is brought about by the expectoration of the morbid products of the exudation, and further, and chiefly, by their absorption into the circulation. If this be true of an acute trouble, is it not also applicable to a chronic asthenic one?

Further, the increase of rapidity in the circulation means that the same blood is brought more frequently to the lungs to be oxygenated, — an increase in the number of times, which we have seen to be equal to 29,622 additional times, *per diem*. This would indicate an increase in the activity of the metamorphosis of tissue, and therefore an increased vital force. This is clinically perceptible in the exhilaration that invalids experience on coming to higher altitudes, and by the increase in appetite dependent upon the demand for material to meet the additional metamorphosis.

There is the other side, however, which must be alluded to. An increase in the rapidity of the circulation means an increased flow or tendency of blood to the diseased parts, involving, as it does, a greater activity of these parts. This is temporarily noticeable in every case of phthisis pulmonalis coming to higher altitudes, and is evidenced by an increased expectoration. This, as we have said, may be beneficial by assisting to remove the morbid products; but in enfeebled cases, where the ravages of the disease are great, it may be highly injurious in assisting the already great breaking-down of the tissues. Again: there is an increased demand for oxygen dependent on all of these causes, and, in cases where the amount of lung-tissue involved is so great as to cause a considerable embarrassment of the respiration, this additional strain is not desirable.

2. *Effect on respiration.* — We must now study another effect produced upon the system by an increase in elevation, and that is, the effect produced upon the respiration. Here, too, we shall have to speak of gross results, and leave minutiae unexplained.

Experience shows that the respirations are deepened and fuller, and that they are, at first, at least, increased in number.

This can be explained somewhat in the following way. The nervous action, the effect upon the respiratory centre, etc., is so complicated, that, despite its importance, we shall leave it without attempting its solution; and we shall only attempt an explanation of the quasi physical or mechanical results.

The lungs are elastic bags suspended in a closed cavity. During inspirations the respiratory muscles draw the ribs upwards, enlarge the cavity, and produce a partial vacuum, in consequence of which the air rushes in to fill up this vacuum, and the lungs are inflated.

It is evident that in inspiration the respiratory muscles, in raising the chest-walls, displace a certain amount of air, and overcome a certain resistance due to atmospheric pressure, and that these muscles, accustomed to exert a given amount of force to overcome this resistance (which may be roughly measured by the difference between the positive pressure on the outside and the negative pressure on the inside of the chest-walls), would continue to exert this force, even though the resistance were diminished. As a result of this, we should expect either a greater expansion of the chest from the same expenditure of force, or an increase in the number of inspirations.

The beneficial results of a greater depth of inspiration will be more clearly seen if we contrast it with the bad results of diminished respiration. Ruehle, in Ziemssen's Cyclopaedia, says, —

"The diminished respiration in the upper parts of the lungs, and the exaggerated respiration in the lower parts resulting from this cause, serve to explain the very general fact that pulmonary consumption almost always begins at the apices of the lungs. But there is probably another cause in the peculiar position of these parts. They project from three to four centimetres above the clavicles; and this projecting portion, being situated outside the chest, is subjected to the pressure of the external air. The supraclavicular region sinks in during deep inspiration, and consequently the inspiratory expansion of the apices is less than that of other parts of the lungs."

It is evident, if Ruehle be right, that a diminution of atmospheric pressure means a greater expansion of the apices, due to a diminution of atmospheric pressure bearing on those parts, and also a greater expansion of the entire chest.

There is, however, a theory often advanced, that the greater depth of respiration is due to the fact, that, in consequence of the diminution of the amount of oxygen dependent upon the decreased atmospheric pressure, an individual will have to breathe more frequently and deeper to gain the amount of oxygen necessary for aerating the blood. The theory, it seems to us, is misunderstood, and the question needs investigation.

We have shown that there is an increased demand for oxygen dependent upon an increased tendency of the blood to the lungs.

It is known, also, that the transpiration of gases through tubes, which the bronchi really are, is hindered by a diminution of pressure, and that in consequence of this, in a given time, under the same conditions of expansion, etc., less air will enter the lungs at 5,000 feet elevation than at sea-level. This is another cause why the respirations should be either deeper or more frequent.

It is further known that the osmose of gases through a thin septum, as in the lungs, is less rapid the less the pressure, or, in other words, that the rapidity of the osmose of gases is dependent upon the pressure to which they are subjected. This being so, as the density of the oxygen and carbonic acid in the blood is nearly constant, if the density of these gases in the air be diminished, there will be an effect produced upon the rapidity of their osmose. In the case of oxygen, it is claimed that an individual will get less of it at 5,000 feet elevation than the system requires, and that, unless the conditions of respiration be changed, there will be a 'starvation of oxygen,' i.e., an asphyxia. In consequence of all this, it has been claimed that a greater depth and frequency of respiration is demanded to meet this want.

In regard to the osmose of oxygen, we know, that, even though there be a hindrance due to the diminished density of the gas in the air, there is still, on the other hand, an increased rapidity of the circulation, which would favor osmose; and it may be assumed that the effects of these two conditions counterbalance one another.

In regard to a starvation of oxygen being produced by a diminution in the amount of the gas at a higher elevation, the *rationale* is somewhat as follows: there exists in the atmosphere, under all pressures, 23 parts by weight of oxygen. At sea-level, there are 130.4 grains of the gas in every cubic foot, while, at 5,000 feet, this amount will be diminished one-sixth, so that there will only be 108.6 grains to the cubic foot. The question then is, whether a density of 108.6 grains to the cubic foot of air will produce a starvation of the gas in the human economy.

It has been estimated that the tension of the oxygen of the venous blood of the dog is 2.9%, or 22 mm., of mercury. It has been further estimated that the tension of the oxygen of the pulmonary air-cells is at least 10% of the atmospheric pressure, which, at 5,000 feet, would amount to 63.3 mm. of mercury; so that it is evident, that, even under this diminution of pressure, the difference between the density of the oxygen in the inspired air and in that of the venous blood brought to the lungs is sufficiently great to admit of a free osmose.

Further than this, we know that the amount of tidal air passing in and out of the chest of an average man is 500 cc., or 31 cubic inches. Allowing 17 respirations to the minute, this will make 510 litres, or 18 cubic feet, of oxygen inspired *per horam*. At 5,000 feet this air would contain 1,955 grains of oxygen. Now, the absolute absorption of oxygen at sea-level is only five per cent of that contained in the air, and the amount that is absolutely needed each hour, at sea-level, is only 117 grains. As the absolute demand for oxygen is only 117 grains each hour, and as the actual amount contained in the inspired air at an altitude of 5,000 feet is, for the same time, 1,955 grains, it is evident that here, again, the supply is greatly in excess of the demand, and that the term 'starvation of oxygen,' as explanatory of the increased depth and rapidity of the inspirations at high altitudes, is a misnomer.

But in addition to the absorption of oxygen there is the elimination of carbonic acid to be accounted for. It is evident, that, as the tension of the gas in the venous blood coming to the lungs is nearly constant, any diminution of its tension in the air will favor its osmose from the blood to the air, and that the effect produced upon the osmose of this gas by rise of elevation is the reverse of the effect upon the osmose of oxygen.

In concluding this part of our subject, we wish to emphasize the fact that we think that the benefit to be derived from simple elevation, in cases of phthisis pulmonalis, is to be attributed largely to the greater depth of the inspirations, and consequently to the greater distension and activity of all parts of the lungs (the diseased apices as well as the healthy bases), and to the increased elimination of morbid products brought about by the increased rapidity of the circulation.

3. *Ozone.* — In addition to the foregoing reasons for favoring a high altitude in the cure of phthisis, we wish to consider, further, the influence of elevation upon the ozone of the atmosphere.

The assertion is generally made, that, as "we ascend heights, the amount of the ozone rapidly increases;" and yet there does not seem to have been any direct experimentation on this point. If there be more free ozone, it may be due, not to any increased production over that of lower levels, but rather to a diminished consumption. Further than this, the

starch and iodide test is so dependent upon other elements than the simple presence of ozone, that it is not thoroughly reliable. It is also open to the error of reacting to substances other than ozone. Still, admitting the statement that there is more nascent ozone at high elevations, the explanation of its action in the cure of phthisis is still to be sought. Some rather visionary theorists, as it seems to the writer, claim that it finds a direct admission to the diseased spots in the lungs, and, by its poorer oxidizing, it burns up *in loco* the morbid products.

We should rather attribute its influence to the fact, that, where ozone exists free, there is no decomposing matter to be oxidized. It seems to us to be indicative of the existence of pure air, rather than a direct agent in destroying the morbid products in the lungs.

4. *Immunity from phthisis.* — Another argument in favor of elevation in the cure of phthisis is, that at certain heights there exists an immunity from the disease. The disease is not endemic at such elevations.

This is in the nature of negative evidence; but it is certainly valuable as an element of prophylaxis, and we think that it can be applied as an argument in favor of cure. Ruehle (*op. cit.*) says, "A height of *at least* 1,800 or 2,000 feet seems to be requisite for this purpose. Phthisis is rare on the Hartz, Styrian (in Purzgau), and Swiss mountains." Jaccoud (Flint's Practice of medicine, p. 296) "states that the observations for fifteen consecutive years warrants him in asserting, that, in Alpine situations elevated 4,000 feet, tuberculosis is unknown; and especially is this true of villages at an elevation of 5,500 feet." Dr. Irwin reports for Fort Defiance (6,500 feet), north-western New Mexico, "During a service of some seven years in New Mexico and Arizona, I never saw or heard of a case of tuberculous disease amongst the native inhabitants of those territories." And Dr. Denison, in his work entitled 'Rocky Mountain health resorts,' writes, "After having quite thoroughly canvassed the subject among physicians of Colorado, I place the altitude of approximate immunity of this state at 6,000 feet."

Taking a mean of all these quotations, we may safely assert, that, broadly speaking, an altitude of from 5,000 to 6,000 feet affords an approximate immunity from this disease.

5. *An aseptic atmosphere.* — Lastly, we will speak of the influence of elevation in the cure of phthisis in producing an aseptic atmosphere. In these days of germ-theories and of Koch's experiments, we cannot but give emphasis to this element of antisepsis as an element of prophylaxis and cure of phthisis. Professor Tyndall's experiments show the abundance of germs floating in the air at sea-level, and an entire absence of such germs at the altitude of the 'Belle Alp' hotel (7,000 feet). Whether a lower elevation will furnish this aseptic atmosphere has not been proven experimentally; but it would seem to be reasonable to argue that an elevation corresponding to that of immunity from phthisis would furnish such an atmosphere.

Résumé. — There are other elements, such as humidity of the air, temperature, precipitation, etc., more or less dependent upon elevation, which we shall have occasion to speak of more at length. But, to make a *résumé* of our study to this point, we can say that a rise in elevation increases the heart-beat and the rapidity of the circulation, thereby hastening the absorption of the morbid products in phthisis, and increasing the metamorphosis of tissue, and hence the vital force; that it likewise produces greater depth of respirations, and a more healthy action of the diseased portions of the lungs; that it gives a purer air, and affords an approximate immunity from the disease; and, finally, that it affords an aseptic atmosphere, in which the Bacillus tuberculosis does not exist. The extent of elevation desirable for the production of this effect can be stated to be at least 5,000 feet.

Having arrived at these conclusions, it remains for us to apply them to our subject. By consulting table I., columns i. and ii., it will be seen, that, of all the resorts for the cure of phthisis in this country, the eastern slopes of the Rocky Mountains alone furnished the desirable elevation. The distance between Denver and Santa Fé is in the neighborhood of 375 miles in extent. Throughout this whole extent, pleasant locations for invalids are to be found at elevations varying from 5,000 to 6,000 feet.

(*To be continued.*)

HISTOLOGY OF INSECTS.

Inspired by Weissmann's well-known researches on the post-embryonic development of insects, Viallanes has studied the structure and changes of various tissues, principally in Musca vomitoria, but also in other insects during their metamorphoses. His results occupy nearly an entire volume,[1] and make an important addition to knowledge, the more welcome because the author deals chiefly with those tissues which have heretofore been least worked

[1] Vol. xiv. sér. vi. of Ann. sc. nat., zool.